80-FM-34
(Supersedes 79-FM-1)

JSC-16728
AUG 14 1980

Level B/C Software Ground Navigation Program

Delta-T Processor

(NASA-TM-82184) LEVEL B/C SOFTWARE GROUND NAVIGATION PROGRAM. DELTA-T PROCESSOR (NASA) 45 p HC A03/MF A01 CSCL 22A

N80-31446

Unclas
G3/16 30957

Mission Planning and Analysis Division

August 1980

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

80FM34

80-FM-34
(Supersedes 79-FM-1)

JSC-16728

SHUTTLE PROGRAM

LEVEL B/C SOFTWARE GROUND NAVIGATION PROGRAM

DELTA-T PROCESSOR

By R. K. Osburn and J. K. Weaver
Mathematical Physics Branch

Approved: ______________________
Emil R. Schiesser, Chief
Mathematical Physics Branch

Approved: ______________________
Ronald L. Berry, Chief
Mission Planning and Analysis Division

Mission Planning and Analysis Division

National Aeronautics and Space Administration

Lyndon B. Johnson Space Center

Houston, Texas

August 1980

PREFACE

The purpose of this internal note is to document the functional and detailed software requirements for a Mission Control Center (MCC) ground navigation processor designed to compute the instantaneous downtrack error in a specified Orbiter onboard navigation state vector. These requirements, in preliminary working paper form, were delivered and reviewed with Flight Control Division/ Ground Data Systems Division/IBM (FCD/GDSD/IBM). The processor (known as the Delta-T Processor (DTP)) has been implemented and verified, and is currently being used to support Space Transportation System-1 (STS-1) mission simulations.

CONTENTS

Section		Page
1.0	INTRODUCTION	1
1.1	PURPOSE AND SCOPE	1
1.2	BACKGROUND	1
1.3	OPERATIONAL USAGE	3
2.0	ACRONYMS AND SYMBOLS	3
3.0	FUNCTIONAL REQUIREMENTS	5
4.0	DETAILED FORMULATION AND IMPLEMENTATION REQUIREMENTS	5
4.1	QUEUEING THE DTP	5
4.1.1	MED Queues	5
4.1.2	Software Queues	6
4.2	INPUT PARAMETER VALIDITY CHECKS	7
4.3	INITIALIZATION	7
4.4	DTP ENABLED DDD	7
4.5	VECTOR FETCH	8
4.6	BATCH FETCH	8
4.7	ANCHOR VECTOR GENERATION	8
4.8	EPHEMERIS GENERATION	9
4.9	PROCESSING	9
4.9.1	Observation Computation	10
4.9.2	Partial Computation	10
4.9.3	Delta-T Computation	11
4.10	TERMINATION	11
4.10.1	DTP Queue	11
4.10.2	DTP Enabled DDD	11
4.11	ERROR PROCESSING	11

Section		Page
4.11.1	Error Termination	11
4.11.2	Error Descriptions	12
4.11.3	Error Processing Considerations	12
4.12	DISPLAY PROCESSING	13
4.12.1	General	13
4.12.2	DTP Table Displays (DTP-1 and DTP-2)	13
4.12.3	DTP Plot Display (DTP-3)	14
4.13	RESPONSE TIME	16
5.0	CONTROL REQUIREMENTS	16
6.0	DISPLAY REQUIREMENTS	16
7.0	REFERENCES	17
APPENDIX A		A-1
APPENDIX B		B-1

TABLE

Table		Page
I	MED DTP INITIALIZATION	18

FIGURES

Figure		Page
1	Format for DPT-1 display	19
2	Format for DPT-2 display	20
3	Format for DPT-3 display	21

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of the Delta-T Processor (DTP) is to compute the instantaneous downtrack error in a specified Orbiter onboard navigation state vector recovered via downlink telemetry. The downtrack error, expressed in units of time, is computed based on current incoming Earth-based range and Doppler navigation tracking data and the ground selected onboard navigation state vector. The computed time difference when used to modify the timetag of the vector used for onboard navigation will reduce the instantaneous downtrack error in this vector to within the threshold of the DTP, the input data, and the onboard software. This threshold is currently estimated to be approximately 2 to 4 nautical miles.

The DTP will not be restricted to use only onboard vectors. Any vector, either input via the manual entry device (MED) or accessible via the vector administration table (VAT), may be used. The DTP will not require that both data types be available. It will compute the vector downtrack error based on either or both data types. The processor will be available for use only during Mission Control Center (MCC), low-speed onorbit operation phases. During these phases, the DTP may be used at anytime except during tracking data intervals because they contain more than one planned maneuver, which is currently in the mission plan table (MPT).

1.2 BACKGROUND

The use of range and Doppler navigation tracking data to evaluate or determine the downtrack error in a specified state vector has been used extensively during the Apollo and ASTP projects. It was necessary to use these techniques for both navigation vector evaluation, and for computing and applying corrections to the state vector either before uplink or after the state vector was already onboard.

The need for such empirical corrections arose from unmodeled spacecraft velocity perturbations, which were the result of spacecraft venting, unbalanced attitude maintenance and control thruster firings, and errors in the astrodynamical models and physical constants used in the mission control software. It is anticipated that such empirical corrections will very probably be required during Shuttle Orbiter mission operations; at least until there is some actual flight experience with the Orbiter spacecraft. The Orbiter design is such that there are many vent sources that are uncoupled. Fortunately, most of these are failure or contingency vents, or vents that can be scheduled such that they do not interfere with critical navigation phases. Currently, the only uncoupled vent scheduled to be operating during deorbit preparation is the high load evaporator portion of the Flash Evaporator System. Based on computer simulations of attitude change and attitude maintenance operations (performed by K. L. Lindsay/EH and J. Tuck/LEC), it appears that the spacecraft velocity will almost constantly be perturbed. There will always be a translational velocity perturbation whenever an attitude control thruster is fired. Some of these perturbations occur in a direction that does not affect navigation, and some are almost canceled by subsequent thruster firings. A number of the attitude

control thruster firings are below the threshold of the Orbiter accelerometers; hence, the onboard navigation software will not include them in the navigation computations.

Furthermore, the characteristics of the attitude control system, with respect to the translational velocity perturbations under the wide range of possible operating conditions, are not sufficiently known such that they could be modeled in the ground navigation computations. This possibility will occur only after there is sufficient actual flight experience - if at all. The foregoing remarks are not intended to be critical of the Orbiter design. Experimentation has shown that perfectly coupled attitude control systems are very difficult to achieve. On many unmanned spaceflight projects, where the control systems were designed to be coupled, there were always translational velocity perturbations that affected "early-out" targeting computations.

The empirical correction technique had not, in the past, been automated in the MCC flight system software. Instead, the computations were performed at the ground navigation support console using desktop computers. This approach could be used since the mission timelines and the available Earth-based tracking coverage were such that there was sufficient time to perform and cross-check the computations prior to applying them. For the Shuttle, the planned mission orbital altitudes and orbital inclinations are such that with the existing tracking network, the tracking passes will be relatively short, ranging from 2 to 8 minutes (maximum) and sometimes widely spaced. In addition, the event timelines during critical navigation phases (such as abort-once-around (AOA) and deorbit to entry interface) are such that if a correction to the onboard navigation state is required, it must be computed and uplinked during the same tracking pass. Based on these considerations, DSAD management (then H. W. Tindall, Jr.) directed that the empirical computations be automated in the MCC flight system software for orbital flight test-1 (OFT-1) support (ref. 1).

The proposed DTP correction technique was presented and accepted at the Entry Procedures Working Group Meeting held on August 4, 1978 (ref. 2). This was followed by two joint Flight Control Division/Ground Data Systems Division/Mission Planning and Analysis Division (FCD/GDSD/MPAD) meetings to discuss the preliminary functional design concepts (ref. 3 and 4). During these meetings, it was decided that the easiest way to work with the empirical correction (from an FCD viewpoint) would be to uplink the computed "delta time" and have the onboard software adjust the timetag of the onboard navigation vector. This approach would be easier and take less time than applying the correction on the ground then uplinking and verifying a whole state vector. It was also decided (based on GDSD's recommendation) that the DTP would be designed to work in a cyclical (automatic point-by-point) manner rather than a demand-response manner. The DTP was baselined at a November 13, 1978 BRR meeting (ref. 5). R. K. Osburn prepared the preliminary level C requirements and provided them to GDSD during the week of November 13, 1978. This was followed by an IBM critical design review meeting held on March 29, 1979. The DTP was included in the OFT-1 MCC flight system software on approximately August 1, 1979 and has since been used, where appropriate, during mission simulations. A preliminary assessment of the expected DTP performance and capabilities was presented at the 36th meeting of the Entry Flight Techniques Panel on August 29, 1979 (ref. 6).

1.3 OPERATIONAL USAGE

During mission simulations and flight operations, the DTP will be operated and controlled by the navigation engineer at the ground navigation console. The navigation engineer will be responsible for evaluating the quality and validity of the incoming tracking data, evaluating the performance of the DTP, and recommending to the Flight Dynamics Officer (FDO) the actual delta-time (delta-T) correction to be used.

The FDO will select the specific downlinked state vector to which the correction is to be applied and ensure that the vector is transferred to the preselected VAT slot. Following computation and validation of the time correction, the FDO will relay the delta-T to the Flight Director for voice uplink to the Orbiter.

During other times of onorbit mission operations where a delta-T is not scheduled or required to be uplinked, the ground navigation engineer will be using the DTP as part of the continuous process of state vector validation and spacecraft ephemeris maintenance.

2.0 ACRONYMS AND SYMBOLS

AOS	acquisition of signal
AV	anchor vector ID control parameter
CRT	cathode ray tube
D_{ON}	observed Doppler for the Nth data frame
D_{1N}	nominal computed Doppler observation for the Nth data frame
D_{2N}	perturbed computed Doppler observation for the Nth data frame
DC	differential correction
DDD	digital display driver
DTE	digital television equipment
DTP	Delta-T Processor
DTP-1,2,3	DTP displays 1, 2, and 3, respectively
ENCKE	SMCC numerical integration processor
FDO	Flight Dynamics Officer
GMT	Greenwich mean time
ID	identifier
IND	START/STOP indicator control parameter

K	plot scale factor control parameter
LSIP	Low-Speed Input Processor
MED	manual entry device
MF	total number of valid data frames in a batch fetched for DTP processing
MPT	mission plan table
N	number of data frames processed by the DTP
NI	numerical integration
OCM	observation computation module
PET	phase elapsed time
R_{ON}	observed range for the Nth data frame
R_{1N}	nominal computed range observation for the Nth data frame
R_{2N}	perturbed computed range observation for the Nth data frame
STA	station-to-be-processed control parameter
t_{START}	start time of a maneuver
t_{STOP}	stop time of a maneuver
T	anchor time of the batch being processed by the DTP
TT	threshold time control parameter
V_N	spacecraft velocity at the time of the Nth data frame
VAT	vector administration table
VEH	vehicle/ephemeris ID control parameter
wrt	with respect to
$\partial DT/\partial R_N$	partial of downtrack position error with respect to the range observation for the Nth data frame
$\partial DT/\partial D_N$	partial of downtrack position error with respect to the Doppler observation for the Nth data frame
Δt_{RN}	computed delta-T based on range data for the Nth data frame
Δt_{DN}	computed delta-T based on Doppler data for the Nth data frame

Δtp	perturbation applied to the nominal ephemeris to obtain the perturbed ephemeris

3.0 FUNCTIONAL REQUIREMENTS

The DTP shall be designed to enable the user to compute a near-real-time estimate of the instantaneous downtrack error in a user-specified state vector. To accomplish this, the DTP shall be capable of processing either or both range and Doppler navigation tracking observations. These observations may either be currently incoming or already resident in the batch history table. In the case of incoming data, the DTP shall be required to operate in a cyclical (automatic point-by-point) manner. In the case of already resident data, the DTP shall be required to process all observations within the design limits of 44 data frames before coming to a normal halt. When processing currently incoming data, it is not required that these data be corrected for refraction effects prior to DTP processing.

The user shall be provided manual entry device (MED) controls to initiate or stop DTP processing; specify the input vector (provided it is in an accessible slot), the start time, and the ground station whose data are to be processed.

The user shall be provided the capability to monitor the DTP processing via a digital display and a plot display. For the plot display, the user shall be provided the capability to change the plot scale factor.

4.0 DETAILED FORMULATION AND IMPLEMENTATION REQUIREMENTS

The following sections document the detailed requirements for the DTP. Appendixes A and B contain detailed flow charts representing a suggested implementation.

4.1 QUEUEING THE DTP

The DTP may be queued by one or more of the following sources:

a. MED
b. LSIP
c. DTP

Of these only a MED queue is manual (i.e., user-initiated). The LSIP and DTP queues are software-generated. It is required that the capability be provided to initialize the DTP for processing, via manual queue, prior to the spacecraft acquisition of signal (AOS) at the tracking station where data are to be processed. The DTP processing should then begin automatically as soon as one or more valid data frames are received.

4.1.1 MED Queues

The user shall have the capability, via the DTP initialization MED, to cause a DTP processing queue to be generated or to stop current DTP processing.

4.1.1.1 The DTP initialization MED

The following six control parameters are specified via the DTP initialization MED:

a. Vehicle/ephemeris ID (VEH)
b. Threshold time (TT)
c. Station-to-be-processed (STA)
d. Anchor vector ID (AV)
e. START/STOP indicator (IND)
f. Plot scale factor (K)

The START/STOP indicator is an optional entry. If defaulted, START shall be assumed. When IND = START, either by direct specification or by default, the first four parameters shall be mandatory entries. When IND = STOP, all other control parameters shall be ignored. The plot scale factor is always optional.

4.1.1.2 MED Processing

Initial processing (including parameter validity checks) of the DTP initialization request shall occur in a MED processor independent of the DTP. The receipt of a valid DTP initialization request shall cause current delta-T processing to terminate. To ensure the execution of such termination requests, DTP initialization MED requests must be processed concurrent with delta-T processing. Following the issuance of the delta-T processing termination request, the START/STOP indicator shall be examined. If IND = START, the first four control parameters must also be included in the MED request. A manual delta-T processing queue shall then be issued based on the user-specified control parameters. If IND = STOP, software queues from the Low-Speed Input Processor (LSIP) shall be inhibited and the DTP shall remain disabled until activated by a subsequent DTP initialization MED request.

4.1.1.3 Manual DTP Queue

When a DTP initialization request is entered and IND = START, a manual DTP processing queue shall be issued by the MED processing software. The DTP, having been disabled by the MED processing software, shall remain disabled until this manual queue is processed. A manual processing queue shall specify all required DTP control parameters.

4.1.2 Software Queues

Software queues for delta-T processing may be generated by the LSIP or by the DTP itself. These software queues shall cause processing to be initiated using previously specified control parameters.

4.1.2.1 LSIP Queues

The generation of low-speed input processing queues shall be activated when the DTP is entered via a manual queue. It shall remain activated until the DTP is disabled via a subsequent manual entry. An LSIP queue shall be generated each time a new valid data frame is saved from the site specified by the user on the DTP initialization request. In general an LSIP queue shall require the refetching of the data batch being processed. The LSIP queues shall not provide any control parameter information. Control parameters used for the previous pass through the DTP shall remain unchanged.

4.1.2.2 DTP Queues

The DTP may queue itself when it completes the processing of a data frame, and additional frames are available for processing without refetching the data batch. The DTP queues shall not provide any control parameter information. Control parameters used for the previous pass through the DTP shall remain unchanged.

4.2 INPUT PARAMETER VALIDITY CHECKS

The format for DTP initialization MED entries is shown in table I. Errors in MED entry format shall be detected by MED processing software. Associated error messages shall be returned via the MED CRT. No delta-T processing shall be required for the generation of these messages.

4.3 INITIALIZATION

Immediately following entry via a manual queue, the DTP must be initialized for processing. This initialization consists of the following:

a. Capture queue values for each of the control parameters.

b. Activate the generation of LSIP queues for the user-specified station.

c. Initialize error flags.

d. Set the number of data frames processed to zero.

e. Enable DTP processing of all queues.

4.4 DTP ENABLED DDD

A DDD shall be provided to indicate to the user that the DTP has been initialized for processing. This DDD shall be illuminated at the time the DTP receives a manual queue to begin processing. It shall remain illuminated until the DTP is deactivated.

4.5 VECTOR FETCH

The DTP shall call the vector fetch routine to obtain the state vector associated with the user-specified input vector ID. If the vector cannot be found, the appropriate error flag shall be set. The vector fetch error shall cause the current pass through the DTP to terminate. A vector fetch error shall also cause the initialization to fail. The DTP shall be disabled prior to the return of control to the system.

4.6 BATCH FETCH

Batch fetch software must be initialized in two ways within the delta-T processing logic. On an initial (N = 1) pass through the DTP, batch fetch software must obtain the ID of the batch to be processed based on the user-specified threshold time and station ID. The batch must then be recovered for processing. On subsequent passes through the software, only the latter operation is required. The batch recovered must meet the following criteria:

a. The data must be from the station specified by the user on the initialization MED.

b. The batch anchor time must be equal to or later than the threshold time specified by the user or the initialization MED.

c. If more than one batch meets the first two criteria the one with the earliest anchor time shall be chosen.

If the batch ID cannot be determined or the batch identified cannot be found, appropriate error flags shall be set and the current pass through the DTP shall be terminated. On an initial pass through the DTP, the batch anchor time T shall be used to drive the ENCKE for generation of the anchor vector. The total number of valid data frames MF shall be obtained from the data batch. On subsequent DTP, passes the anchor time shall not be required.

4.7 ANCHOR VECTOR GENERATION

On initial (N = 1) passes through the DTP the batch fetch software shall provide the anchor time T of the batch to be processed. The DTP shall check the MPT to see if any nonzero delta-V maneuvers occur within the data batch. If more than one maneuver is found within the time interval spanned by the batch DTP, processing shall be terminated, an error indication shall be passed to the user, and the DTP shall be disabled. If there is not more than one maneuver in the time interval spanned by the batch, the DTP shall call ENCKE to integrate the input vector from the vector time VT to the anchor time T of the batch to be processed. Integrator options for this integration will be determined as follows:

a. For no maneuvers

1. Integrate the input vector from time VT to time T using NO maneuver option

b. For one maneuver, use t_{START} = maneuver start time, t_{STOP} = maneuver stop time

1. If VT > T, use NO maneuver option

2. If VT = T, no integration required

3. If VT < T

(a) If $VT \leq t_{START} \leq t_{STOP} \leq T$, use maneuvers in integration

(b) Otherwise use NO maneuver option

The vector obtained at time T by this integration shall then be integrated to T - 3 minutes using NO maneuvers. If the ENCKE call is successful (i.e., no NI errors) the resulting vector shall be stored as the anchor vector for use in the generation of the required nominal and perturbed ephemerides. If an NI error is produced the appropriate error flag shall be set, the current pass through the DTP shall be terminated, and the DTP shall be disabled.

4.8 EPHEMERIS GENERATION

On the initial pass through the DTP, the generation of one ephemeris (based on the stored anchor vector) is required. The ENCKE integrator shall be used to integrate the stored anchor vector forward, storing ephemeris points at one-beta-step intervals, for a minimum of 15 minutes. No maneuvers shall be considered in the generation of the nominal or perturbed ephemerides. If the ENCKE call produces a numerical integration error, the appropriate error flag shall be set. The current pass through the DTP shall be terminated and the DTP shall be disabled. Processing shall continue if the ephemeris is successfully generated. A perturbed ephemeris, referred to as ephemeris-2, is also required. Vectors from ephemeris-2 may be obtained by accessing ephemeris-1 at times of $T - \Delta TP$ where ΔTP is the desired perturbation and T is the desired vector time.

If the integration is terminated due to re-entry (300 000 feet error) the DTP shall requeue the integration for a reduced interval so that the ephemeris is generated to but not below the 300 000 feet limit. Subsequent processing shall then continue normally.

4.9 PROCESSING

The DTP shall process an individual data frame on each queue. Consequently, each of the operations discussed below shall be carried out for a single data frame in each pass through the DTP. For discussion purposes, the following sections contain the processing of the Nth valid (i.e., saved for DC) data frame. The DTP shall have the capability to process either C-band or S-band data. Any

observation types not present in a data frame because of invalid, missing (i.e., C-band Doppler), or edited data shall be ignored by the processor.

4.9.1 Observation Computation

The observation computation module (OCM) shall be called to compute range and Doppler observations based on both the nominal and perturbed ephemerides. The nominal range and Doppler observation shall be identified as R1N and D1N, respectively, where N is the number of the data frame. The perturbed range and Doppler observations shall be identified as R_{2N} and D_{2N}, respectively.

4.9.2 Partial Computation

The partials of downtrack error with respect to the range and Doppler observations from the Nth data frame shall be computed as follows:

$$\left(\frac{\partial DT}{\partial R}\right)_N = \frac{V_N\ (\Delta TP)}{R_{2N} - R_{1N}}$$

$$\left(\frac{\partial DT}{\partial D}\right)_N = \frac{V_N\ (\Delta TP)}{D_{2N} - D_{1N}}$$

where $\left(\frac{\partial DT}{\partial R}\right)_N$ is the partial of downtrack position with respect to the range observation for the Nth data frame, $\left(\frac{\partial DT}{\partial D}\right)_N$ is partial of downtrack position with respect to the Doppler observation for the Nth data frame, V_N is the spacecraft velocity at the time of the Nth data frame computed based on ephemeris one, Δtp is the timetag adjustment applied to the state vector used to compute the perturbed ephemeris, and R_{1N}, R_{2N}, D_{1N}, and D_{2N} are the computed observations defined in section 4.9.1.

4.9.3 Delta-T Computation

Two estimates of the delta-T (Δt), based on range and Doppler observations, respectively, shall be computed for the Nth data frame as follows:

$$\Delta t_{RN} = \left(\frac{\partial DT}{\partial R}\right)_N \left(\frac{R_{ON} - R_{1N}}{V_N}\right)$$

$$\Delta t_{DN} = \left(\frac{\partial DT}{\partial D}\right)_N \left(\frac{D_{ON} - D_{1N}}{V_N}\right)$$

where Δt_{RN} is the value of Δt based on the range observation, Δt_{DN} is the value of Δt based on the Doppler observation, R_{ON} is the observed range, and D_{ON} is the observed Doppler. The remaining elements are defined in sections 4.9.1 and 4.9.2.

4.10 TERMINATION

4.10.1 DTP Queue

Prior to termination, the DTP shall determine whether additional data frames are available for processing without recalling batch fetch software. If additional frames are available, the DTP shall issue a DTP queue (sec. 4.1.2.2) for processing. If no additional frames are available, the DTP shall return control to the executive system without issuing any additional processing queues.

4.10.2 DTP Enabled DDD

The DTP enabled DDD shall be extinguished when the DTP is disabled.

4.11 ERROR PROCESSING

4.11.1 Error Termination

If DTP processing is terminated by an error, only the control parameters and related general information shall be output to DTE for display. All data for individual data frames shall be blanked.

4.11.2 Error Descriptions

4.11.2.1 Error 1

Error 1 shall occur when the vector fetch routine is unable to find the vector specified by the user as the input vector. This error shall cause an error termination. The associated error message shall be INPUT VECTOR NOT FOUND.

4.11.2.2 Error 2

Error 2 shall occur when batch fetch logic fails to find a batch for the station and threshold time specified on the initialization MED. This error shall cause an error termination. The associated error message shall be NO BATCH AVAILABLE FOR PROCESSING.

4.11.2.3 Error 3

Error 3 shall occur when the ENCKE integrator returns a numerical integration (NI) error during the propagation of the input vector to anchor vector time. This error shall cause an error termination. The associated error message shall be NI ERROR IN ANCHOR VECTOR GENERATION.

4.11.2.4 Error 4

Error 4 shall occur when more than one nonzero delta-V maneuver is defined in the MPT at a time within the data arc of the batch to be processed. This error shall cause an error termination. The associated error message shall be MORE THAN ONE MANEUVER IN DATA ARC.

4.11.2.5 Error 5

Error 5 shall occur when the ENCKE integrator returns an NI error during the generation of the nominal ephemeris. This error shall cause an error termination. The associated error message shall be NI ERROR IN NOMINAL EPHEMERIS GENERATION. The vehicle trajectory falling below 300 000 feet prior to the end of the nominal ephemeris shall not be treated as an NI error termination (sec. 4.8).

4.11.3 Error Processing Considerations

Errors 1 through 3 will occur prior to the incrementing of the frame counter. Error 4 will occur after the frame counter is incremented, and for this error the counter must thus be decremented prior to the termination. An error termination shall cause the DTP to be disabled. An additional initialization MED request shall then be required to initiate processing.

4.12 DISPLAY PROCESSING

4.12.1 General

There shall be three DTP displays, two table displays, and one plot. The two table displays are required to ensure that sufficient data frames may be processed to reach a point past maximum elevation for the tracking pass. The two table displays shall be referred to as DTP-1 and DTP-2, respectively. The plot shall be referred to as DTP-3. The following sections discuss the contents of these displays and the processing logic that controls their generation.

4.12.2 DTP Table Displays (DTP-1 and DTP-2)

4.12.2.1 Display Parameters

The following parameters, or a subset of these parameters (sec. 3.12.2.2.) shall be displayed on the DTP-1 and DTP-2 displays.

a. Initialization control parameters

(1) Vehicle ID
(2) Station ID
(3) Threshold time (GMT)
(4) Input vector ID

b. DTP processing status

(1) Processing status indicator
(2) Batch ID
(3) GMT of last update
(4) Phase elapsed time (PET) of last update

c. For each data frame processed

(1) Frame number
(2) Elapsed time, in minutes/seconds, from frame 1
(3) Elevation angle
(4) Computed range residual
(5) Partial of downtrack error with respect to the observed range residual
(6) Delta-T based on range
(7) Computed Doppler residual
(8) Partial of downtrack error with respect to the observed Doppler residual
(9) Delta-T based on Doppler

4.12.2.2 Display Modes

The DTP table displays shall be updated on each pass through the DTP. These displays shall be generated in one of two modes, each representing one of the termination modes.

a. Nominal mode

    All display parameters shall be computed and updated. Error messages shall be displayed if generated, and the GMT and PET of the last display update shall be updated. Display parameters for invalid or missing observation types and/or data frames shall be blanked.

b. Error mode

    Control parameters and processing status indicators shall be updated to reflect those for which the error occurred. Error messages shall be displayed, and the GMT and PET of last display update shall be updated.

4.12.2.3 Display Processing

The DTP displays shall be updated on each pass through the DTP. The first 22 data frames processed shall be displayed on DTP-1. The next 22 data frames shall be displayed on DTP-2. Frames processed beyond 44 shall not appear on either the DTP-1 or DTP-2 displays.

4.12.2.4 Display Formats

a. DTP-1: Figure 1 shows the format for the DTP-1 display.

b. DTP-2: Figure 2 shows the format for the DTP-2 display.

4.12.3 <u>DTP Plot Display (DTP-3)</u>

4.12.3.1 Display Parameters

The following parameters or a subset of these parameters (sec. 4.12.3.2) shall be diplayed on the DTP-3 display.

a. Initialization control parameters

    (1) Vehicle ID
    (2) Station ID
    (3) Threshold time (GMT)
    (4) Input vector ID

b. DTP processing status

(1) Processing status indicator
(2) Batch ID
(3) GMT of last update
(4) PET of last update

c. For each data frame processed

(1) Delta-T based on range, to be plotted with a character R
(2) Delta-T based on Doppler, to be plotted with a character D
(3) Elapsed time, in minutes, from frame 1.

d. Other information

(1) K-factor for the vertical plot scale
(2) Batch time in GMT
(3) Time of the first plotted data frame in GMT

4.12.3.2 Display Modes

The DTP plot display shall be updated on each pass through the DTP. The display shall be generated in one of two modes, each representing one of the two termination modes.

a. Nominal mode

All display parameters shall be computed and updated. Error messages shall be displayed if generated, and the GMT and PET of the last display update shall be updated. Display parameters for invalid or missing observation types and/or data frames shall be blanked.

b. Error mode

Control parameters and processing status indicators shall be updated to reflect those for which the error occurred. Error messages shall be diplayed, and the GMT and PET of last display update shall be updated.

4.12.3.3 Display Processing

The DTP plot display (DTP-3) shall be updated on each pass through the DTP. The plot shall display delta-T versus elapsed time from frame 1. Values of delta-T shall be displayed over a vertical range of $\pm$ 4K (where K is the user-vertical scale) and a horizontal range of 10 minutes beginning at the time of frame 1. If the vertical scale is not specified, a value of K = 0.5 seconds shall be assumed. Computed delta-T's based on the range and Doppler observation from a data frame shall be represented on the plot as R and D, respectively.

4.12.3.4 Display Format

Figure 3 shows the format for the DTP-3 display.

4.13 RESPONSE TIME

The DTP will be used during an extremely time critical phase of mission operations. It is required that the DTP be capable of processing up to 44 frames of data in not more than 20 seconds.

5.0 CONTROL REQUIREMENTS

The only control required for DTP operation is the DTP initialization MED (sec. 4.1.1). The following parameters shall be specified via this MED.

a. Vehicle ID
b. Threshold time
c. Station ID
d. Input vector ID
e. Start/stop indicator
f. Vertical scale factor

Table I shows the requirements for this MED in detail.

Parameters 1, 3, and 4 shall be mandatory entries if the action code is START. If the code is STOP all other parameters shall be ignored. The vertical scale factor shall be a valid entry by itself or in conjunction with the entry of other parameters.

6.0 DISPLAY REQUIREMENTS

DTP requires three displays and a single DDD for display output. Requirements for the displays are included in section 4.12. The DTP ENABLED DDD requirement is listed in section 4.4.

7.0 REFERENCES

1. Wollenhaupt, W. R.: OFT-1 Onorbit Navigation Performance Briefing. JSC Memorandum FM85 (78-292), July 31, 1978.
2. Wollenhaupt, W. R.: Use of Guam Post Deorbit Tracking Data In Support of OFT-1 Deorbit to EI Nav Computations. JSC Memorandum FM85 (78-314), Aug. 16, 1978.
3. Wollenhaupt, W. R.: Delta-Time Processor for STS-1 Post Deorbit State Vector Correction Based on Guam Tracking Data. JSC Memorandum FM85 (78-376), Oct. 19, 1978.
4. Wollenhaupt, W. R.: MCC/STS-1 Delta-Time Processor, Minutes of Meeting Held October 20. JSC Memorandum FM85 (78-424), Nov. 28, 1978.
5. Wollenhaupt, W. R.: Ground Navigation, Onorbit Items Presented at BRR, November 13, 1978. JSC Memorandum FM85 (78-433), Dec. 12, 1978.
6. Wollenhaupt, W. R.: Status Review of Delta T Processor (DTP) Capabilities. JSC Memorandum FM85 (78-361), Sept. 17, 1979.

TABLE I.- MED DTP INITIALIZATION

Parameter number	Description	Logic	Valid entries			
1	Vehicle ID	Mandatory[a]	(1) S (2) P	--	--	A1
2	Threshold time	Optional	Any GMT time in DDD:HH:MM:SS	Current time	Standard MCC time units	Standard MCC GMT format
3	Station ID	Mandatory[a]	Any valid SCT station mnemonic	--	--	A3
4	Input vector ID	Mandatory[a]	Any valid vector ID	--	Standard MCC vector ID's	AAAAXXX
5	Start/stop indicator	Optional	(1) START (2) STOP	START	--	A5
6	Vertical scale factor	Optional	Any Δt in seconds such that $\Delta t>0$	0.5	Seconds	F5.2

[a]These parameters may be defaulted on entry of the vertical scale factor only.

TRAJECTORY - STANDARD FORMAT SIZE 2

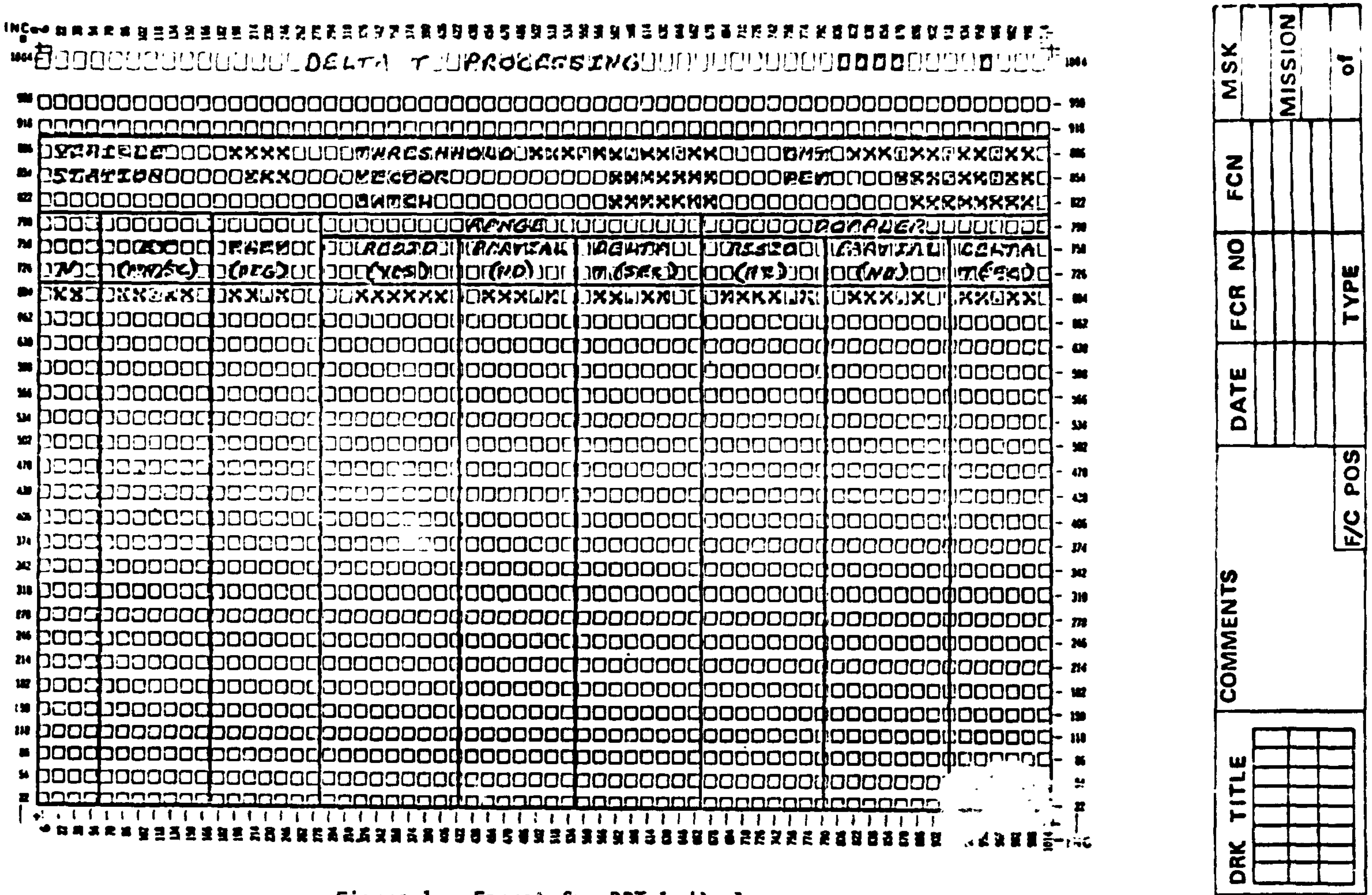
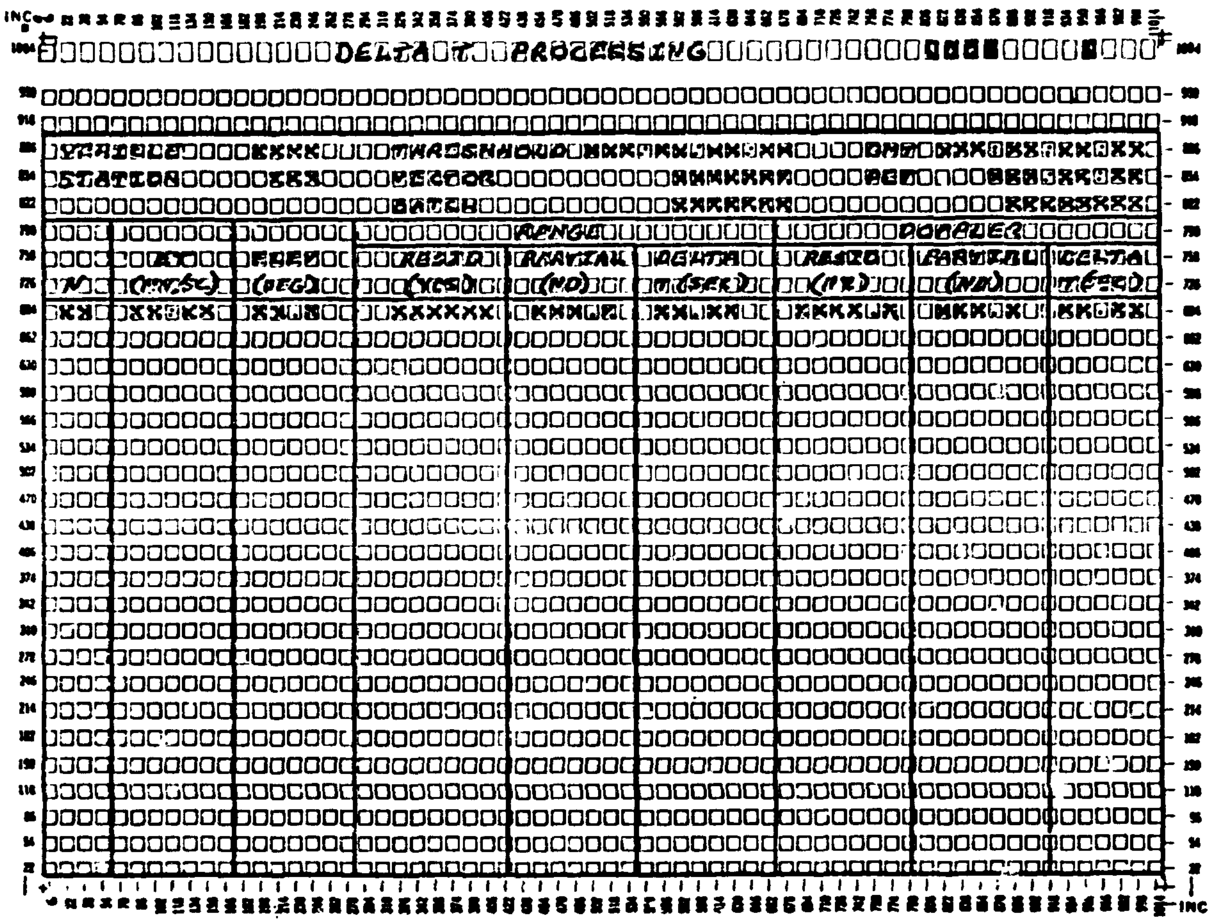


Figure 1.- Format for DPT-1 display.

TRAJECTORY - STANDARD FORMAT SIZE 2



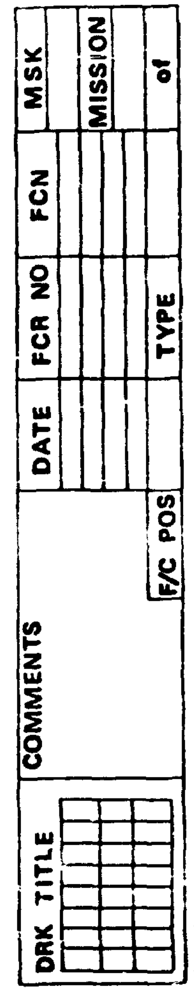


Figure 2.- Format for DPT-2 display.

TRAJECTORY - STANDARD FORMAT SIZE 2

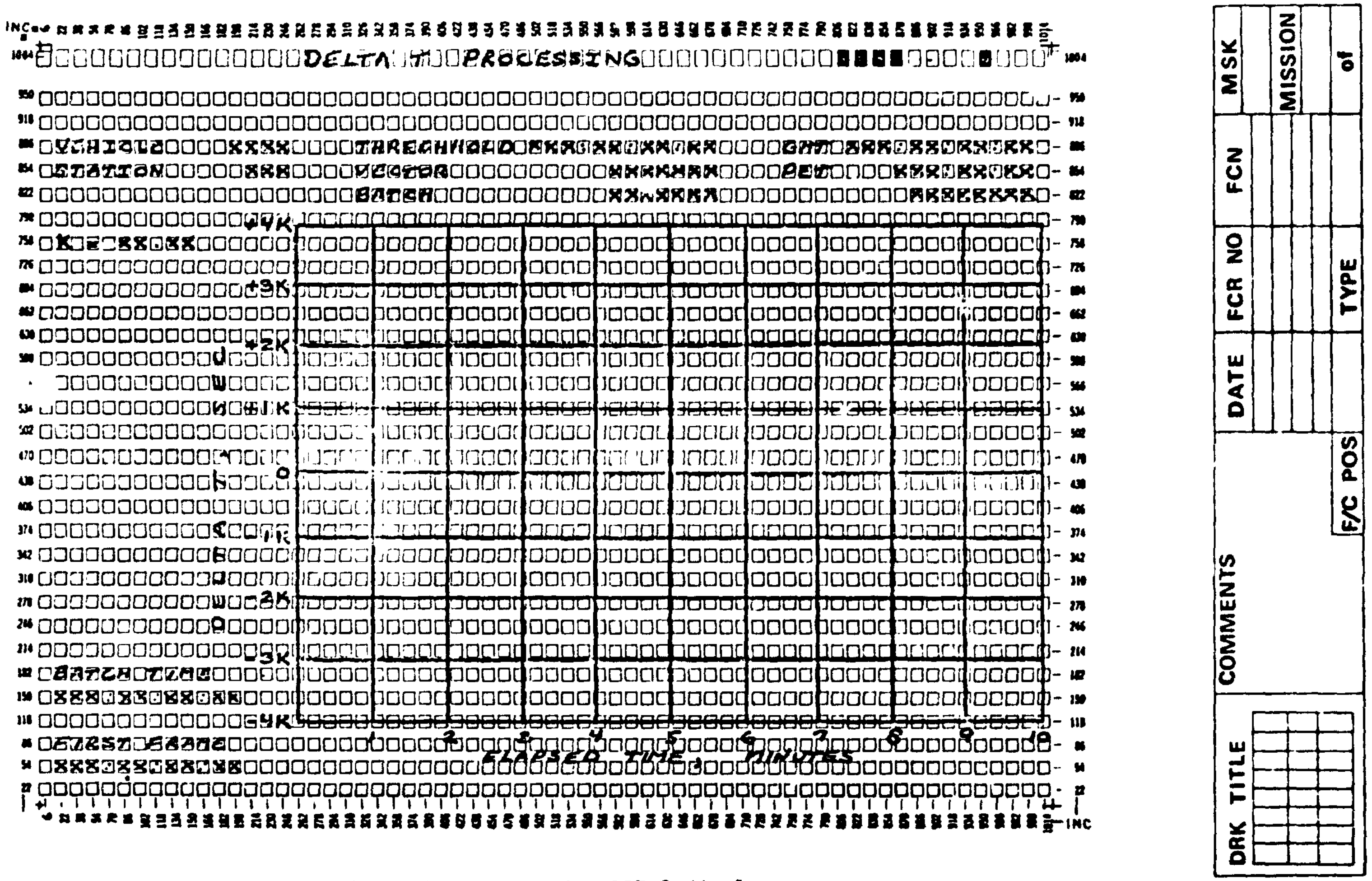


Figure 3.- Format for DPT-3 display.

APPENDIX A

DTP INITIALIZATION MED FLOW

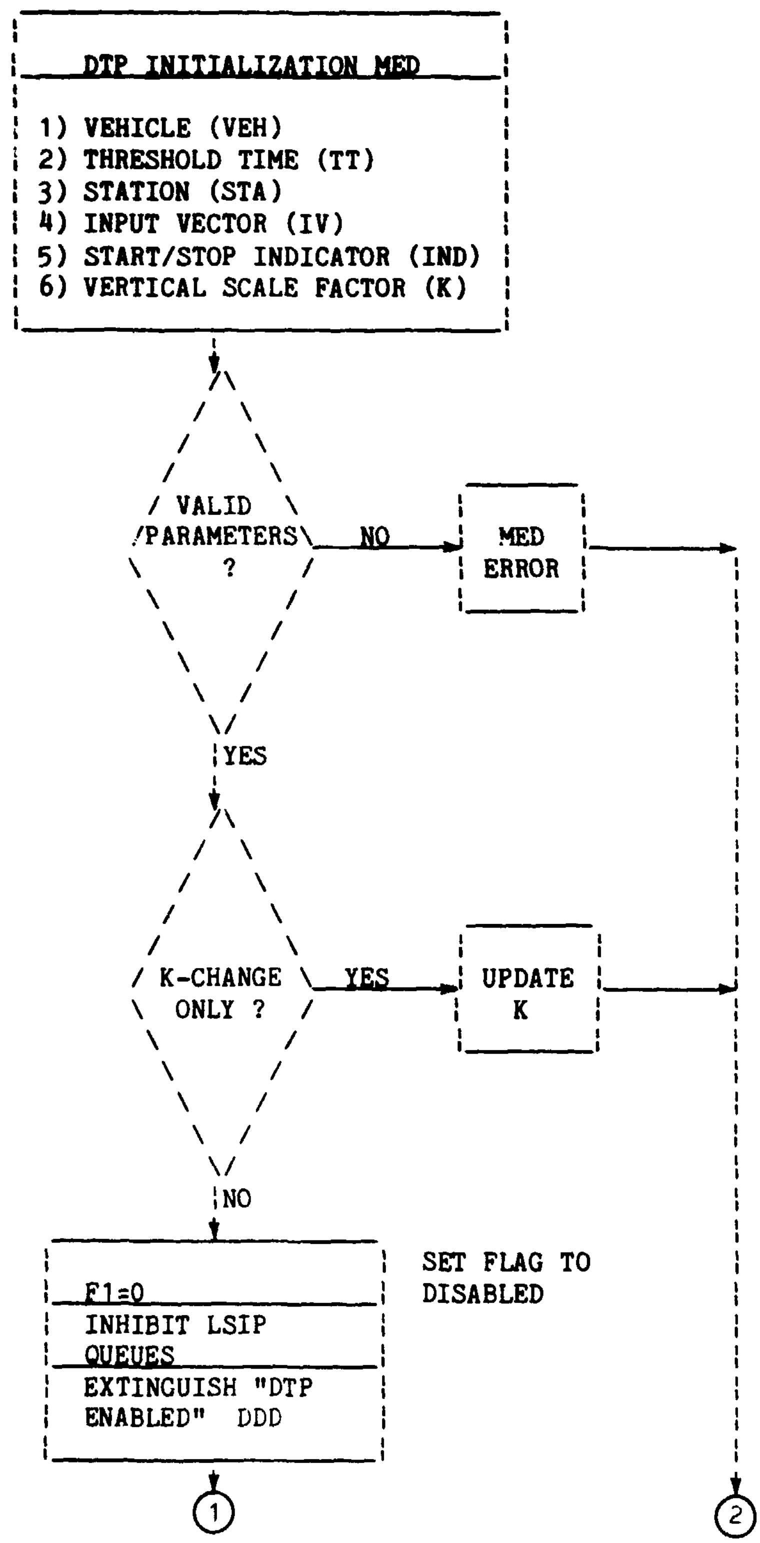


Figure A-1.- DTP initialization MED flow.

80FM34

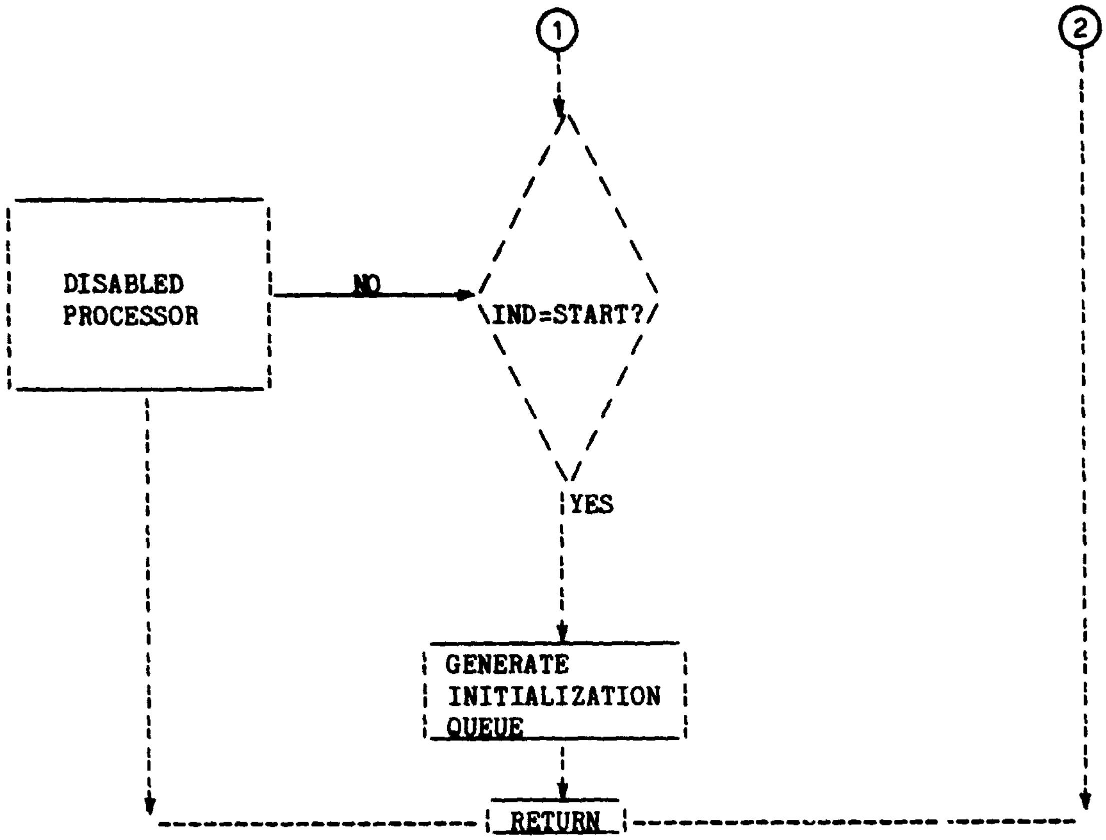


Figure A-1.- Concluded.

APPENDIX B

DTP FLOW LOGIC

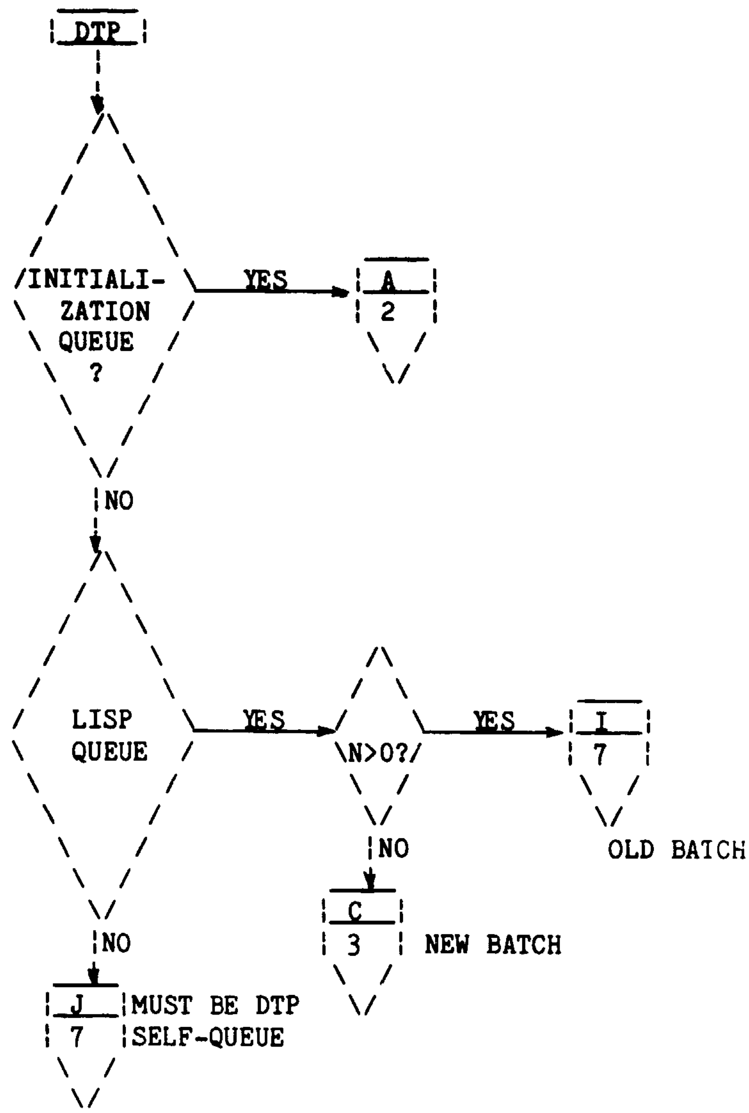
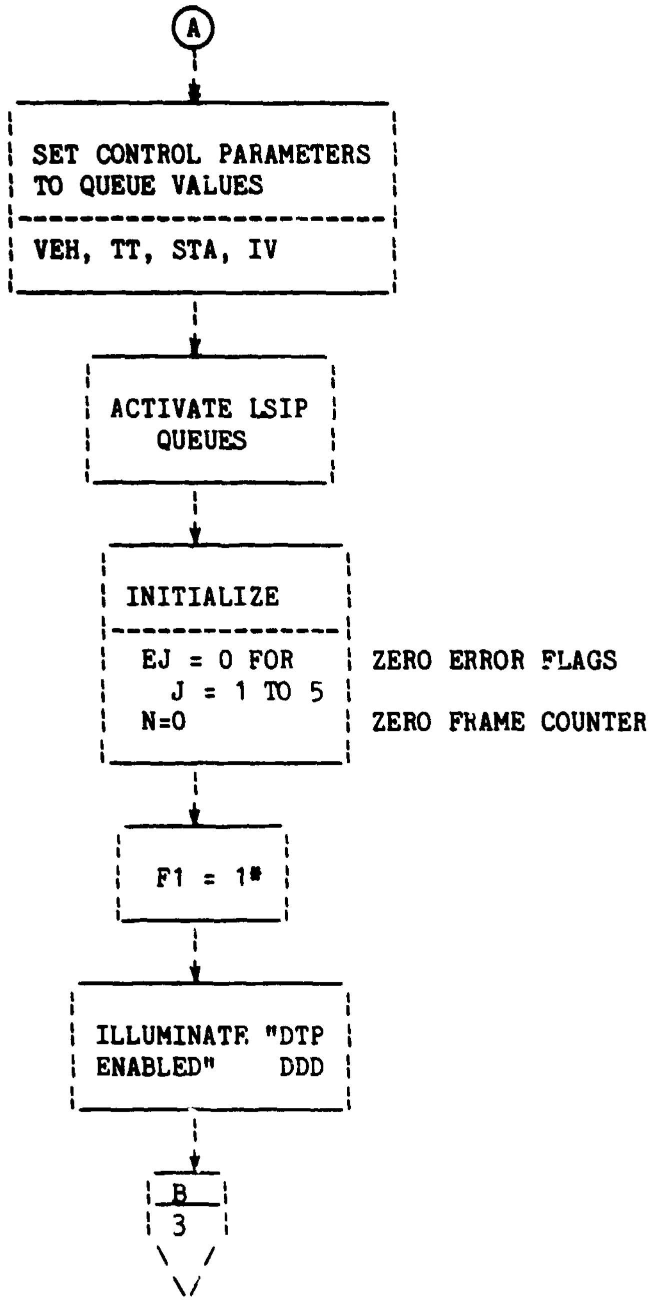
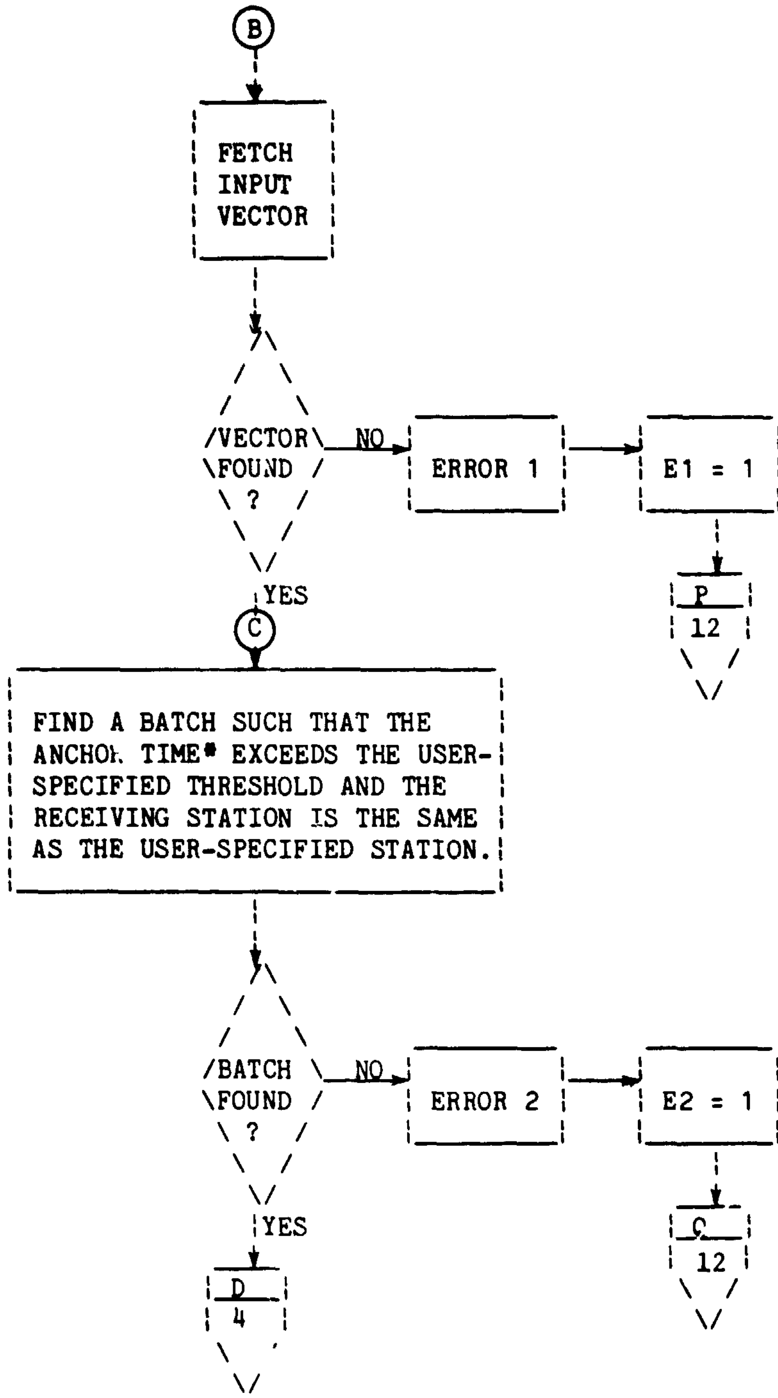


Figure B-1.- DTP flow logic.



* F1 = 0 IMPLIES THE DTP IS DISABLED
F1 = 1 IMPLIES THE DTP IS ENABLED

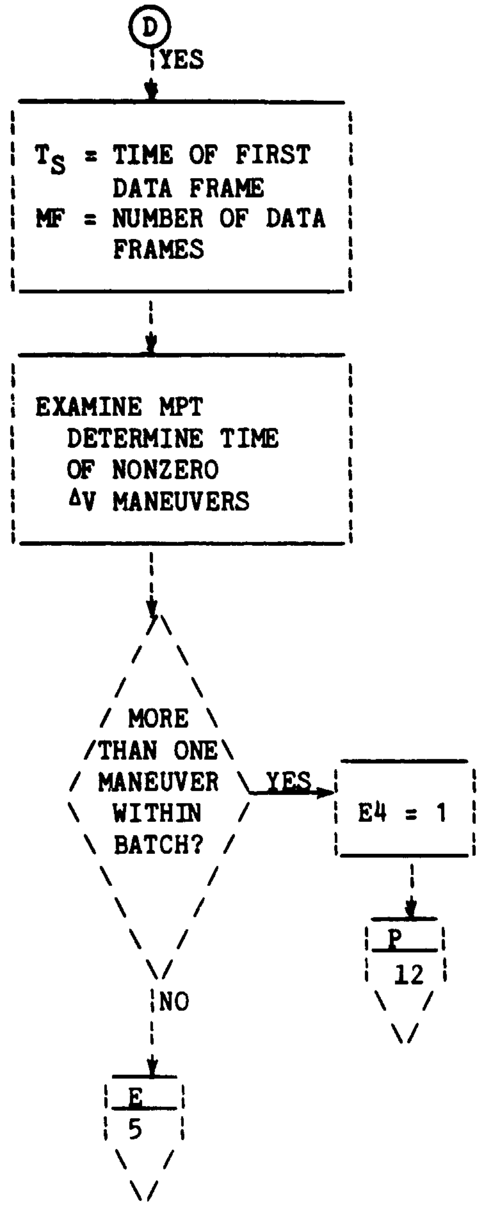
Figure B-1.- Continued.



* TO HAVE AN ANCHOR TIME AT LEAST 1 VALID DATA FRAME MUST HAVE BEEN SAVED.

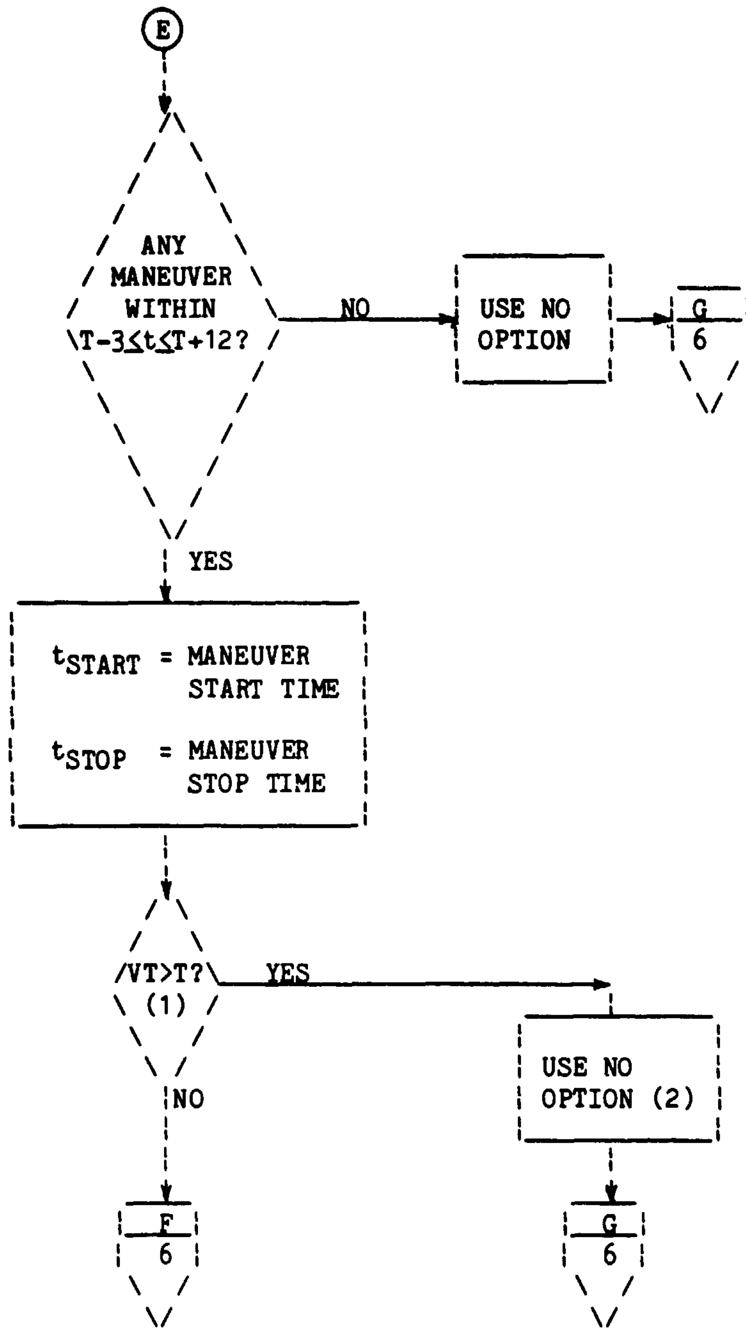
Page 3 of 13

Figure B-1.- Continued.



Page 4 of 13

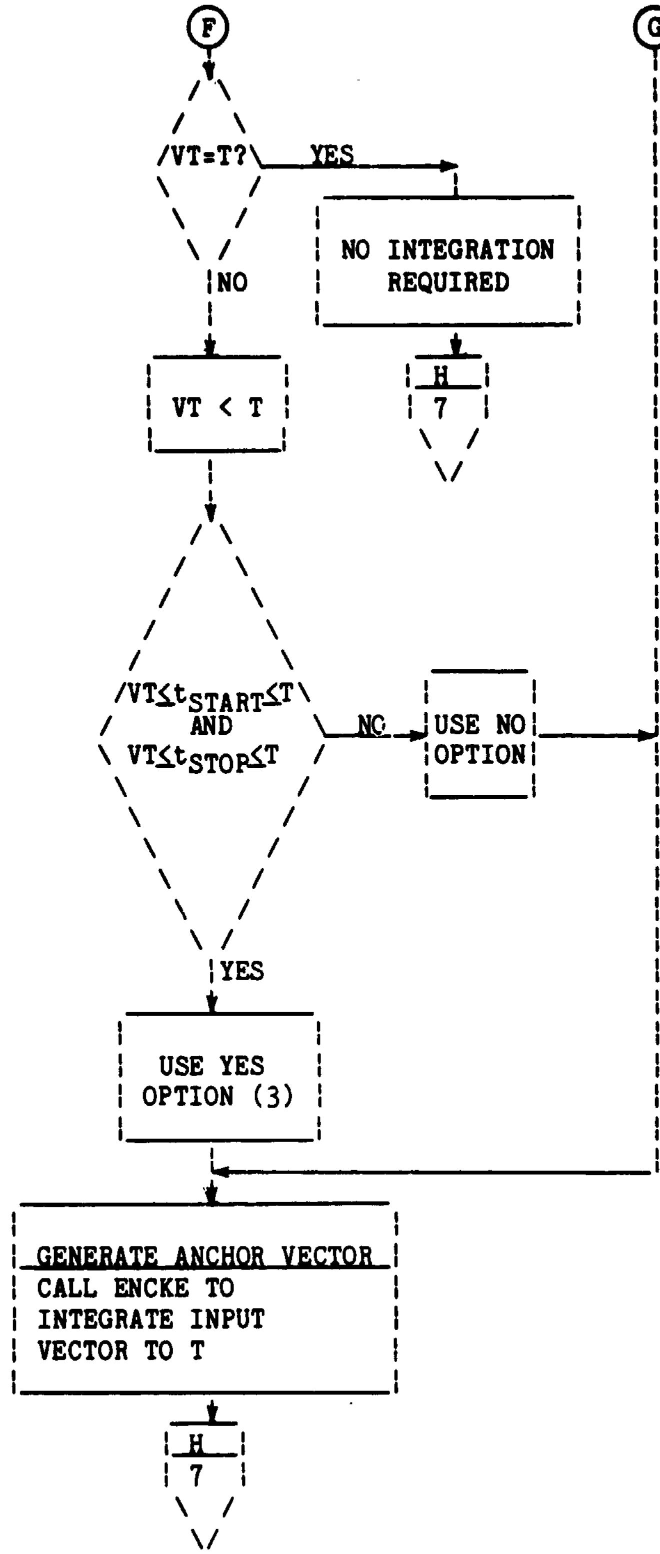
Figure B-1.- Continued.



(1) VT = INPUT VECTOR TIME TAG

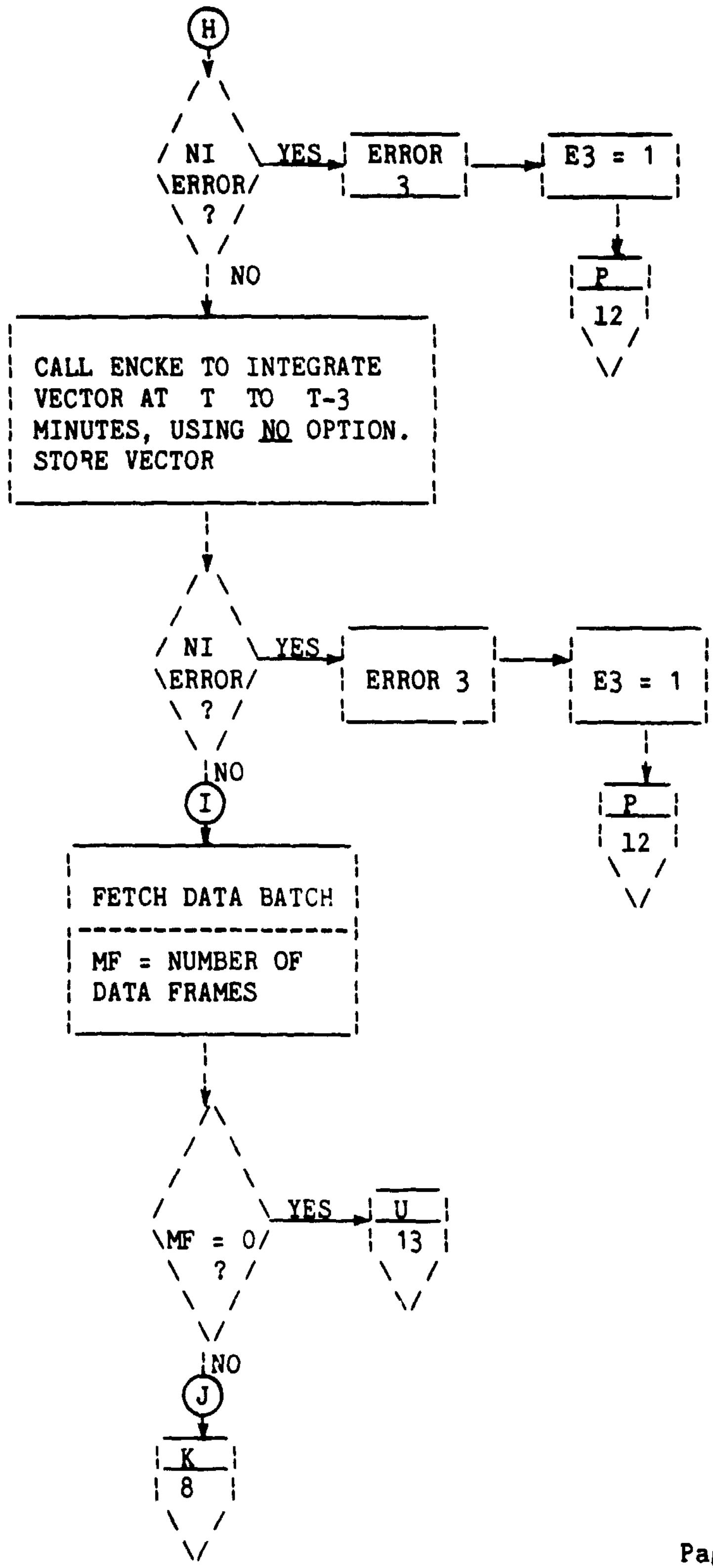
(2) DO NOT CONSIDER MANEUVERS

Figure B-1.- Continued.



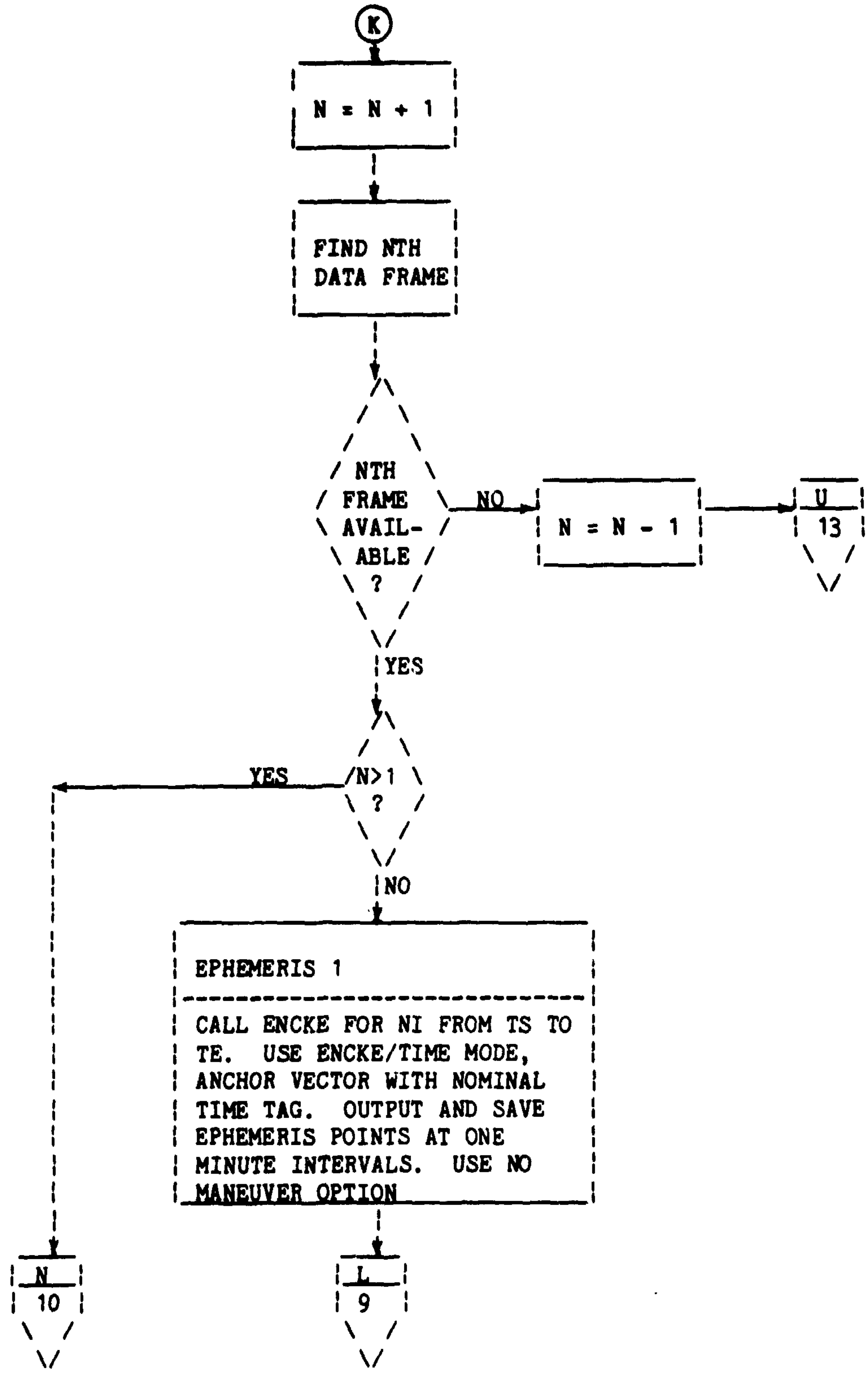
(3) DO CONSIDER MANEUVERS

Figure B-1.- Continued.



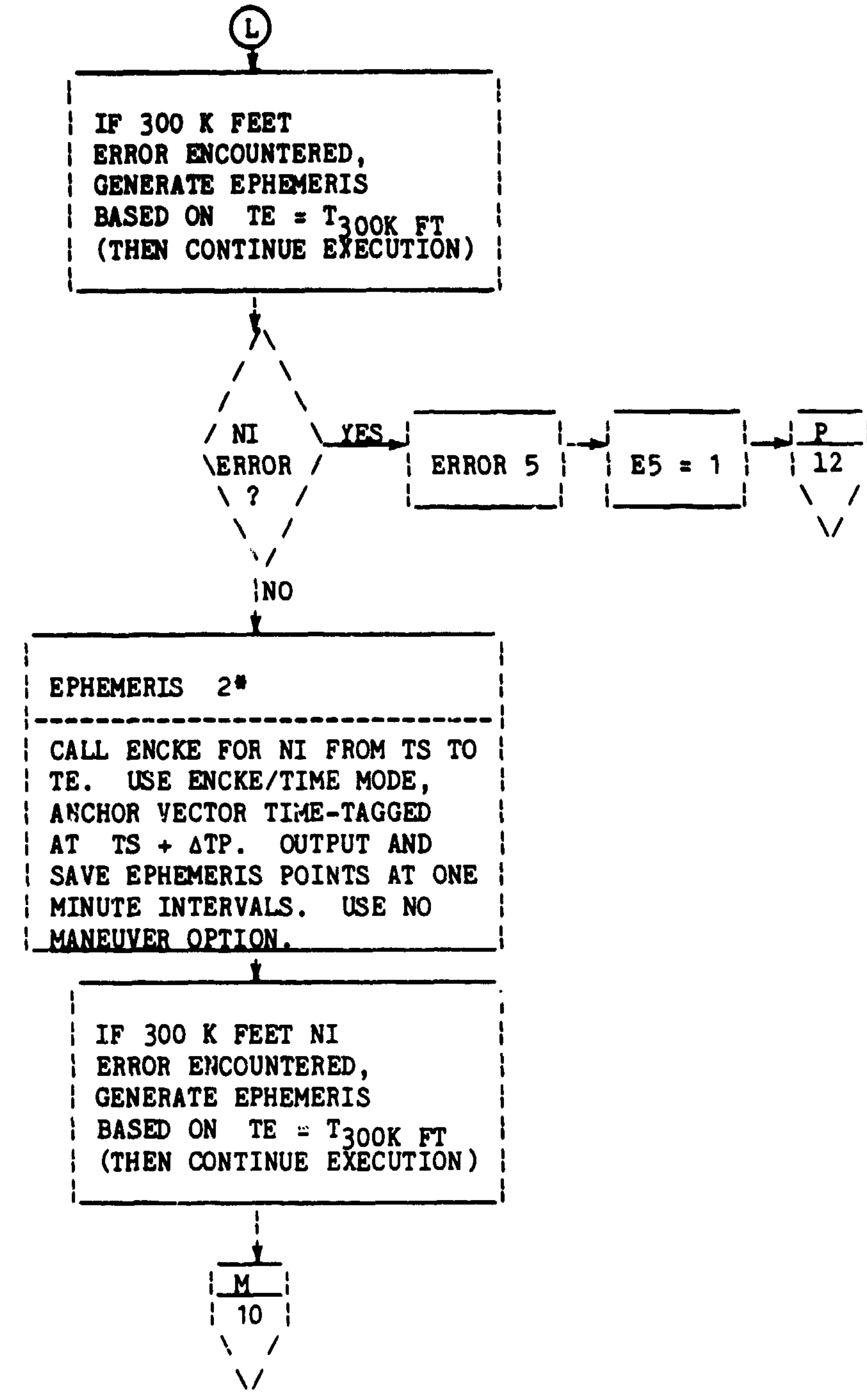
Page 7 of 13

Figure B-1.- Continued.



Page 8 of 13

Figure B-1.- Continued.



* AN INTEGRATOR CALL COULD BE AVOIDED BY USING ONLY ONE EPHEMERIS. AN EPHEMERIS 2 VECTOR AT TIME + COULD BE COMPUTED BY ACCESSING EPHEMERIS 1 AT A TIME OF T - ΔTP.

Figure B-1.- Continued.

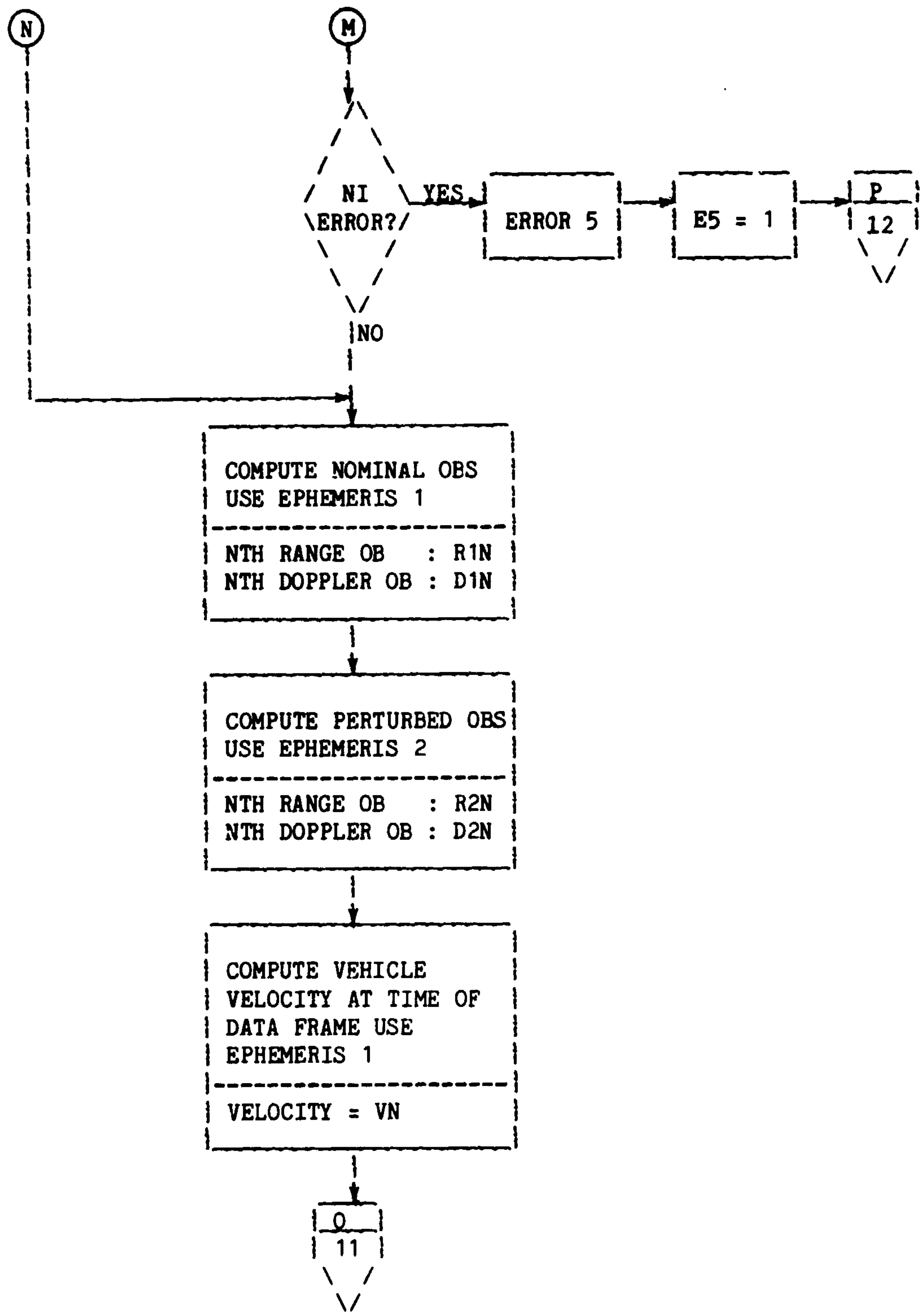


Figure B-1.- Continued.

O

OBTAIN OBSERVED RANGE, RON, AND OBSERVED DOPPLER, DON, FROM DATA BATCH

COMPUTE PARTIALS

$$\left(\frac{\partial DT}{\partial R}\right)_N = \frac{VN\ (\Delta Tp)}{R2N - R1N}$$

$$\left(\frac{\partial DT}{\partial D}\right)_N = \frac{VN\ (\Delta Tp)}{D2N - D1N}$$

COMPUTE ΔT**

$$\Delta T_R = \left(\frac{\partial DT}{\partial R}\right)_N \left(\frac{RON - R1N}{VN}\right)$$

$$\Delta T_D = \left(\frac{\partial DT}{\partial D}\right)_N \left(\frac{DON - D1N}{VN}\right)$$

R
12

**ΔT IS ADDED TO THE INPUT VECTOR TIME TAG TO OBTAIN THE CORRECTED TIME TAG.

Figure B-1.- Continued.

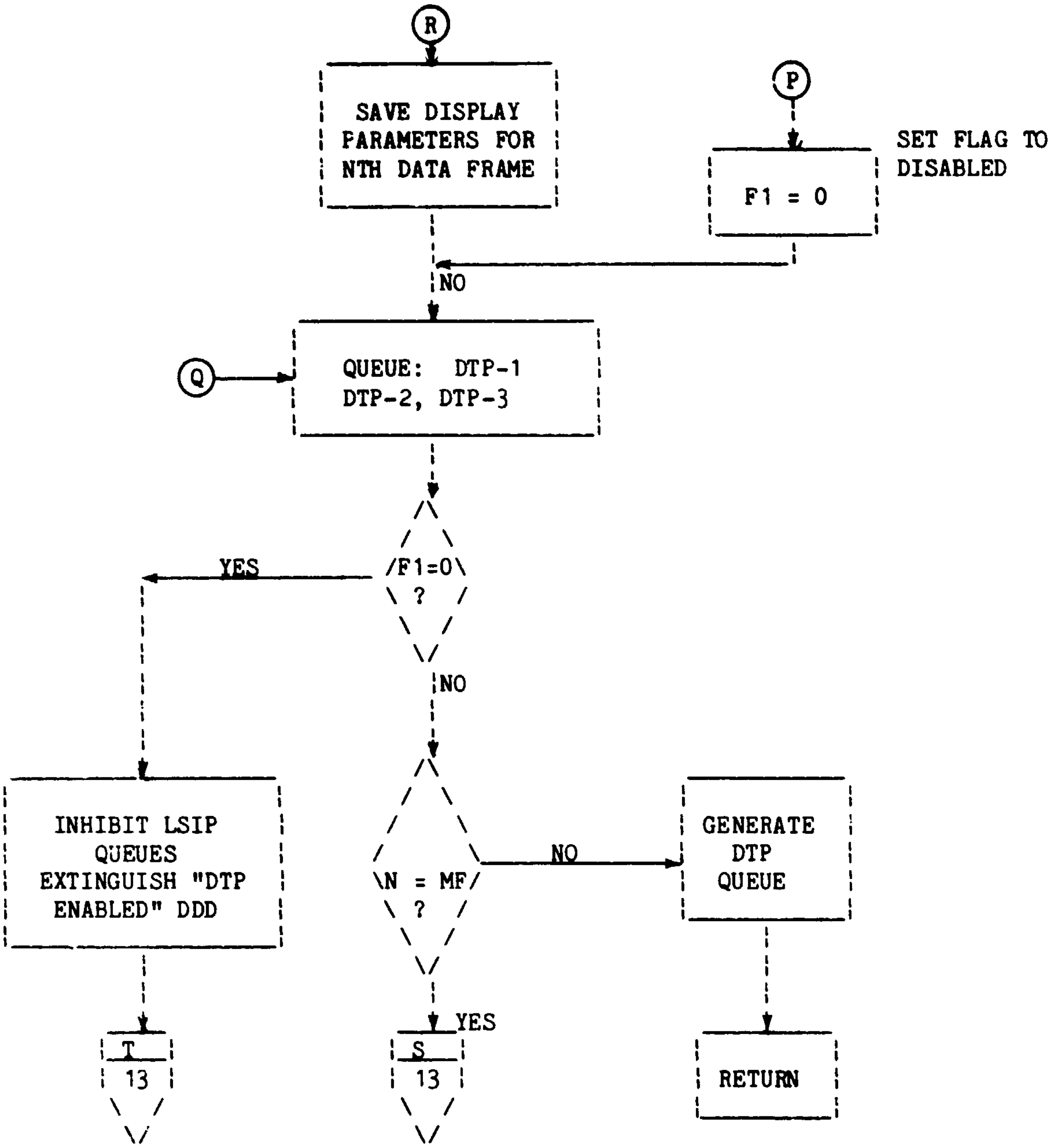
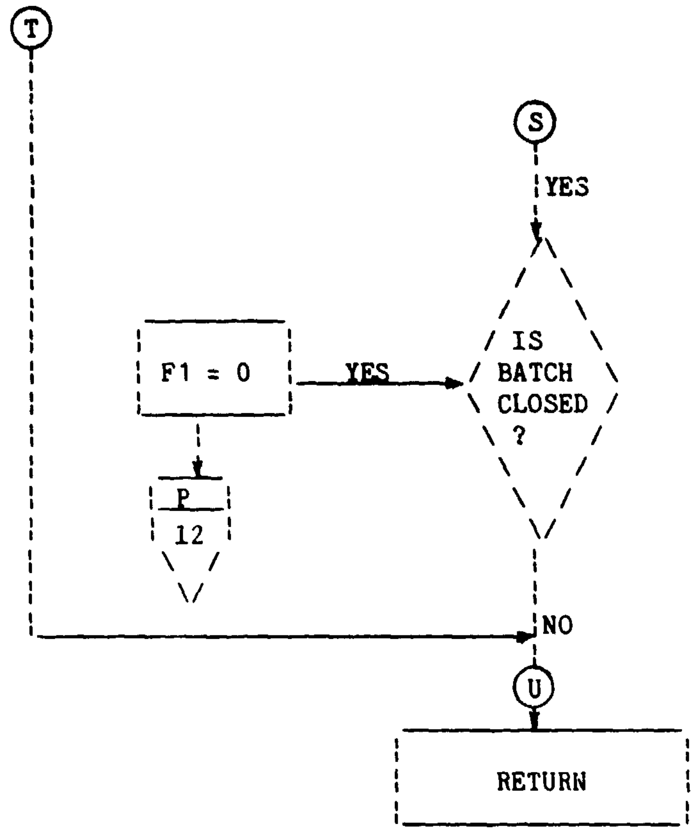


Figure B-1.- Continued.



Page 13 of 13

Figure B-1.- Concluded.

☆ U.S. GOVERNMENT PRINTING OFFICE 1980—671 099/20 87